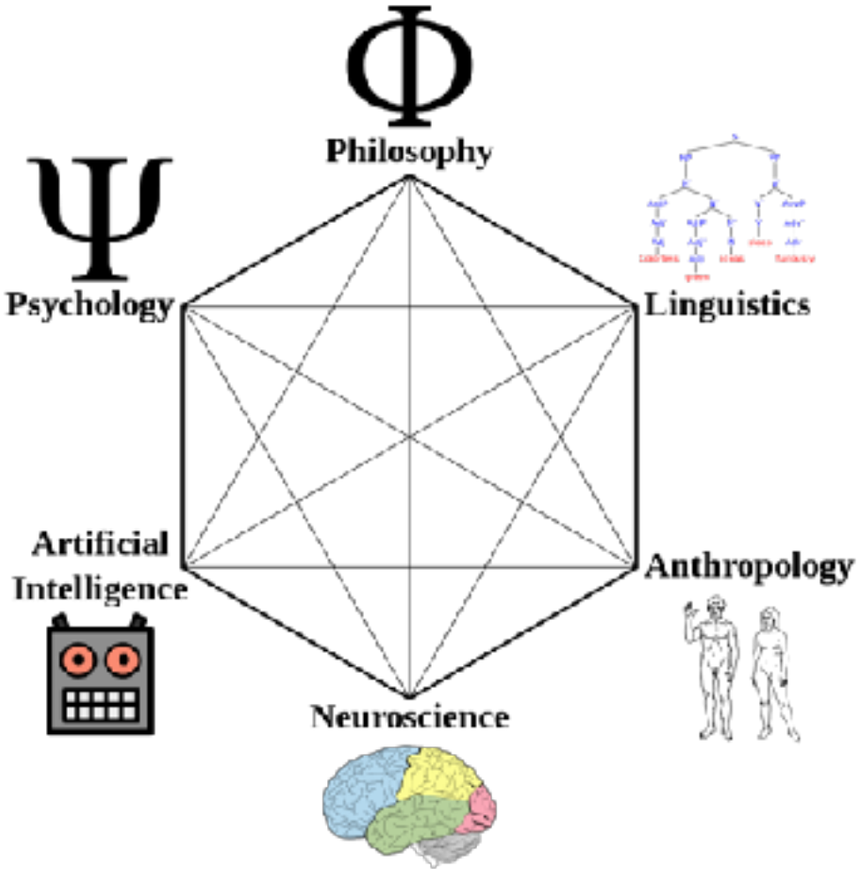
History of Cognitive Science



Greeks

Descartes

Hume/Locke/Kant

Psychology

Neuroscience

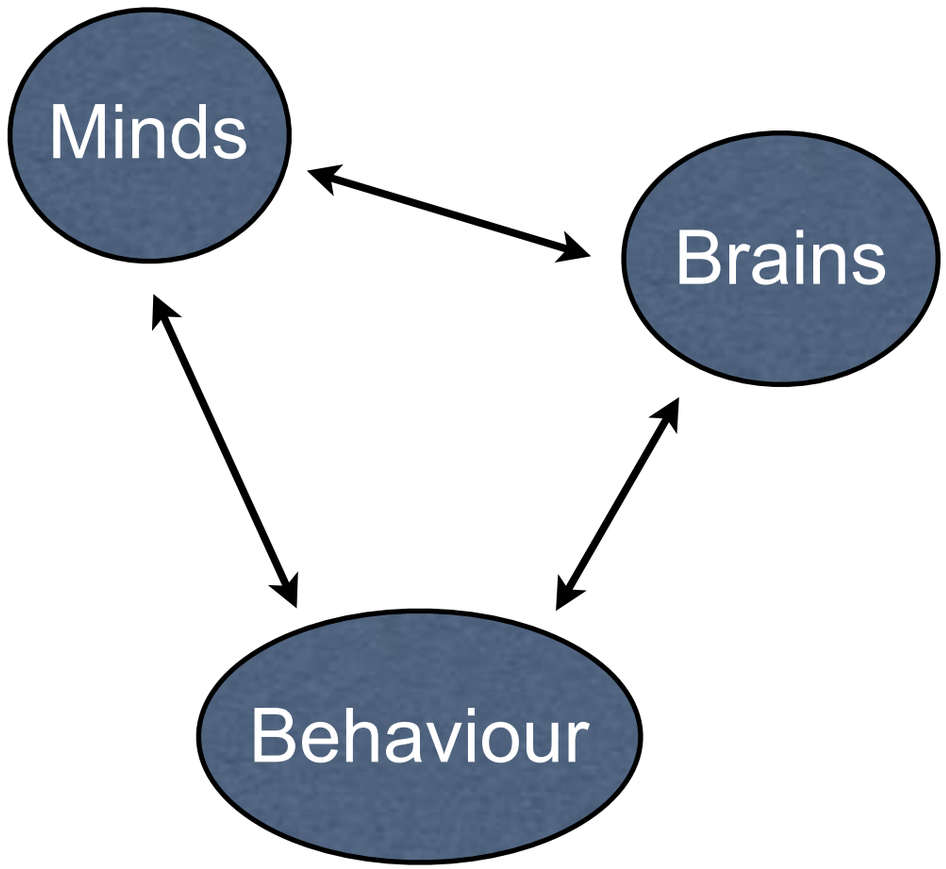
Cybernetics

Artificial Intelligence

Connectionism

Embodiment

*not to scale



Spirit

Consciousness

Intellect

Soul

Psyche

Anima

Atman

Dasein

Experience

cognition

. . . is about *knowing*

. . . hence about the **relationship** between the *knower* and the *known*

“Subject” <—> “World”

Practical epistemology?

Some recurring themes

Dynamist ~ Eternalist

Process ~ State

Rationalist ~ Empiricist

Representationalist ~ Anti-representationalist

Individualist ~ Collective/Social

Monist ~ Dualist (~ Pluralist/Pragmatic)

This is the landscape. These are not questions with answers

The pre-Socratics

Heraclitus

Parmenides

What does it mean to say that something exists? How is this related to time and the present? What is it to persist in time? What is the relation between the world as it appears to us, and as it is?

The pre-Socratics

Heraclitus

All is change/dynamism
You never step in the same river twice
Non-determinism

Parmenides

Eternalism
State-based description
Determinism

The surviving works of Heraclitus and Parmenides are mere fragments of poems. We know little of their actual philosophy.

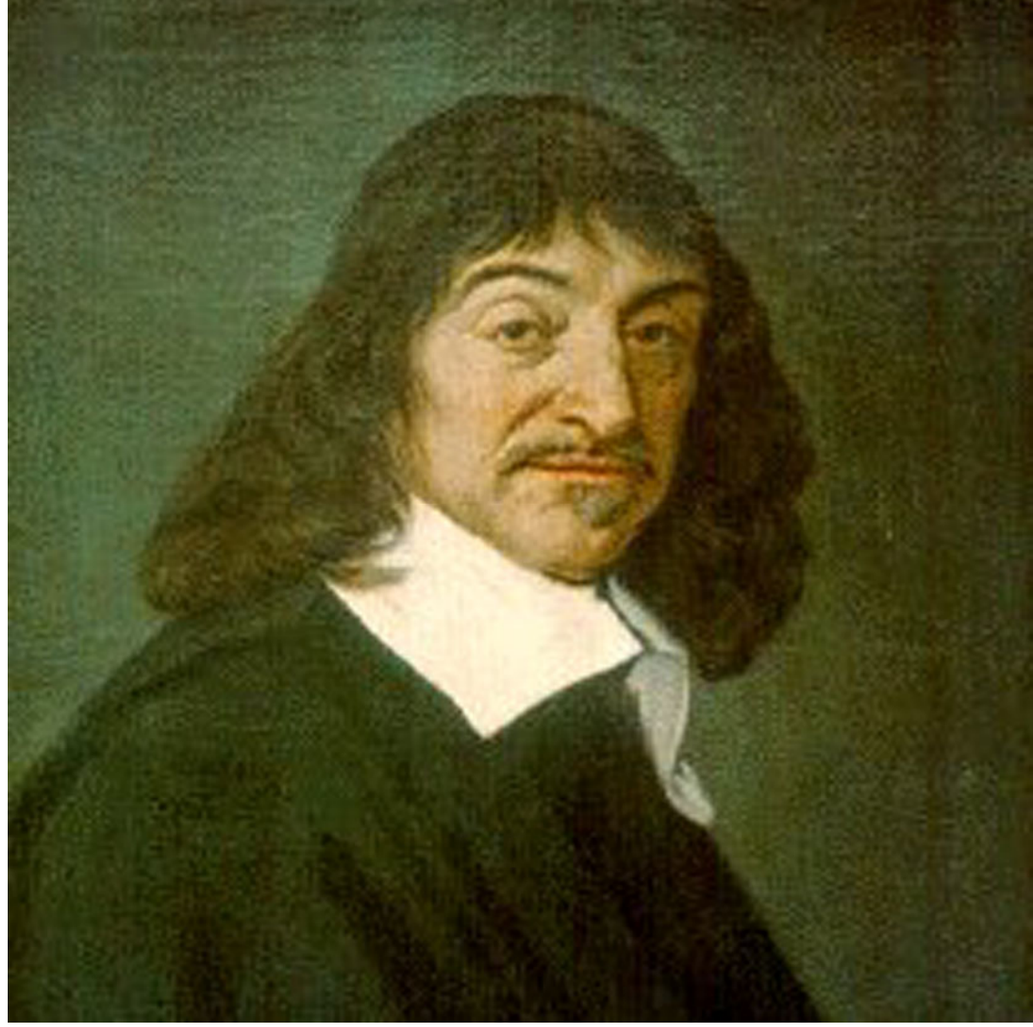
For us, they will serve as landmarks, to distinguish fundamentally different ways of coming at things.

Heraclitus: the indubitable reality of the lived now

Parmenides: that which indubitably exists

We skip about 2,000 years.

René Descartes (1596-1650)



Strongly *rationalist*

The further the mind is taken away from its proper objects – logic and pure reason – the more likely it is to fall into error.

The purpose of philosophy is to direct the mind away from the confusing images of the senses towards the indubitable truths contained within the mind itself.

A sceptical philosopher, wishing to establish a foundation for true and certain knowledge, recognises that the world of appearances, mediated by the senses may be illusory. He considers what remains after denying the testimony of the senses, and reasons thus:

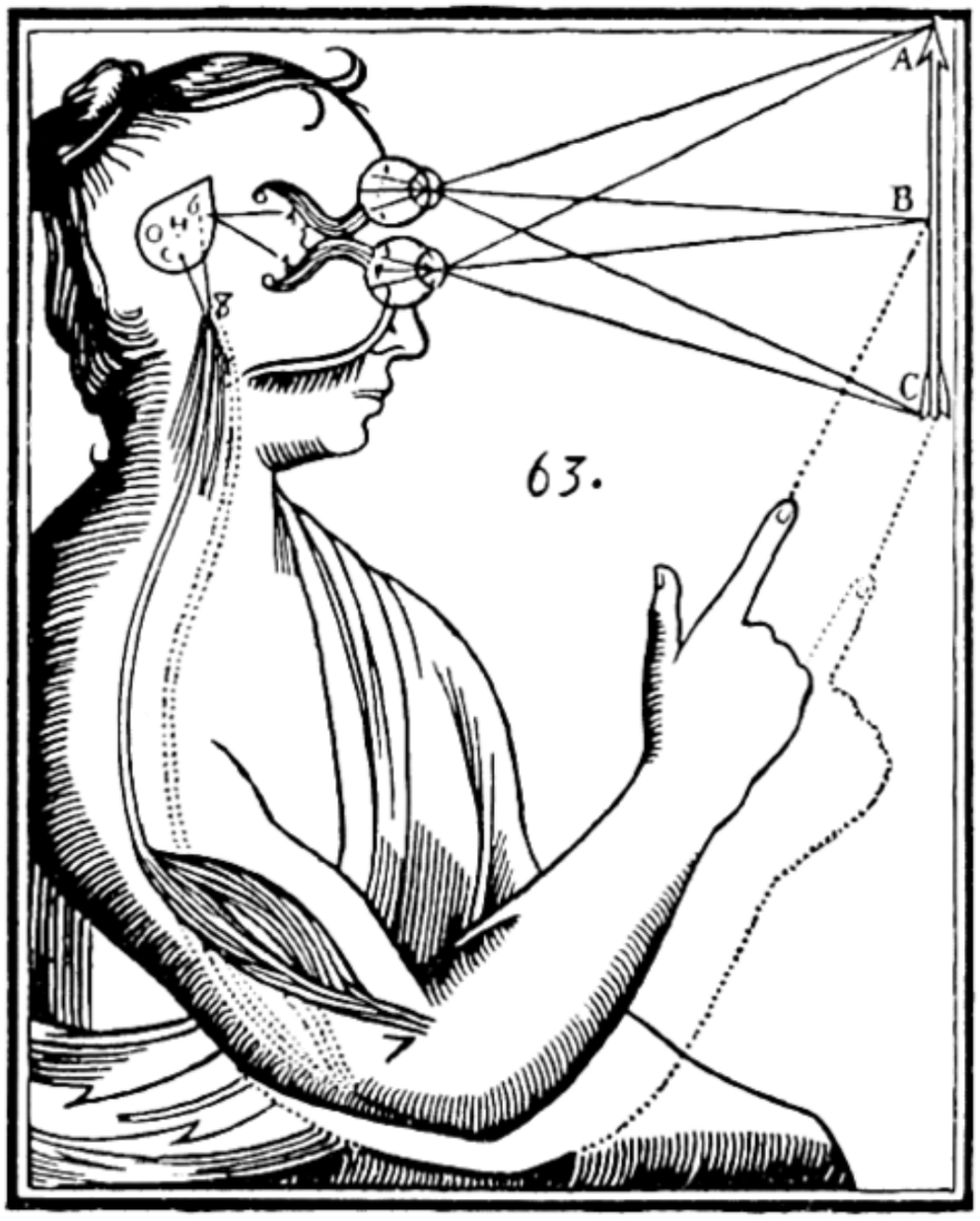
“So after considering everything very thoroughly, I must finally conclude that this proposition, *I am, I exist*, is necessarily true whenever it is put forward by me or conceived in my mind.” (Meditation 2, AT 7:25)

Descartes gave us the ***cogito***: the domain of mind considered as if it were independent of everything else (and hidden, private, unobservable)

Soul

Cogito

Mind



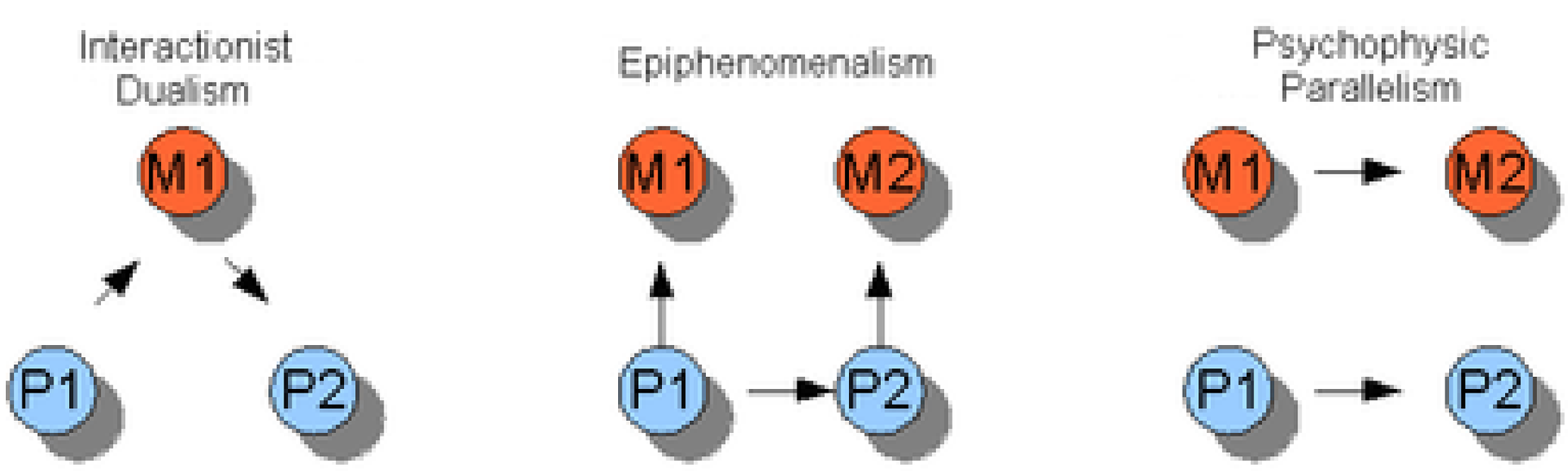
The **mental** (*res cogitans*) and the **physical** (*res extensa*) are seen as different kinds of things.

How they interact is one big problem for ***substance dualism***. Descartes suggested the pineal gland. That satisfied nobody.

Shades of Substance Dualism

Descartes couldn't make substance dualism work. Nor, it seems can anyone else, but not for lack of trying . . .

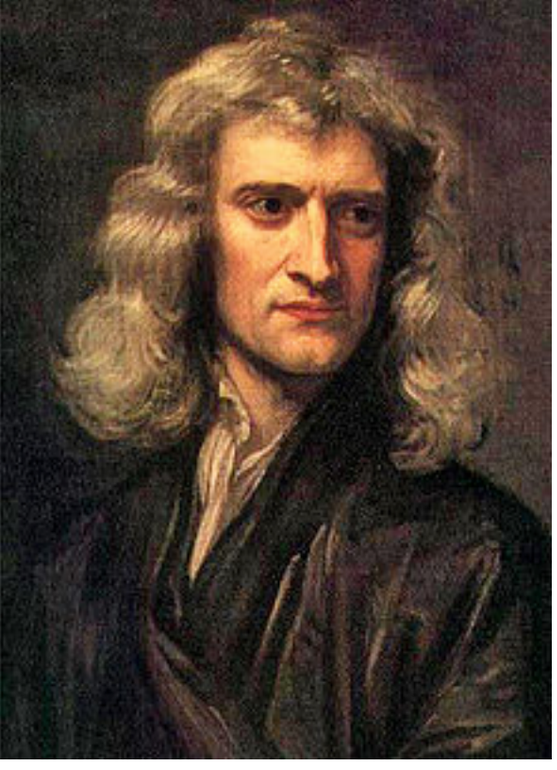
- Interactionism
- Epiphenomenalism
- Psychophysic Parallelism



Source: wikipedia

The body, for Descartes, was an *automaton*, subject to the laws of mechanics (pre-Newton)

All animals were likewise 100% mechanical. Note the strong theological commitment: Humans are fundamentally different from animals. Descartes was not a secular philosopher



Isaac Newton (1642 - 1727) provided a superior account of mechanics, with his three laws of motion.

His view of Natural Law became a foundation stone of the Enlightenment

To this day, many scientists appeal to the notion of a *mechanism* as the archetype of scientific understanding.

But mechanics has its limitations.

Mechanics is the best physics for accounting for the motion of inanimate rigid matter at spatial and timescales appropriate to the human body.

It doesn’t account for animate motion (all living things),
It treats space and time as simple coordinate dimensions,
Caution ought to be applied when appealing to mechanics or mechanical explanation

Descartes' *cogito* places the mind outside of things.

It can lead to the bizarre notion of *solipsism*

Solipsism is the belief that you are the only person with a mind, as you have direct knowledge of your mind and only indirect circumstantial evidence of anyone else's

Solipsism is not a position anyone wants to defend.

Placing the experiencing agentive mind outside nature leads to a view of the world as deanimated, passive, mechanical.

Q: What do people mean when they say something is *physical*?

Q: What role should mechanics play in any account of behaviour?

Q: What is mechanics incapable of dealing with? What are its limitations?

Mind/Brain and Mental/Physical is not a simple distinction

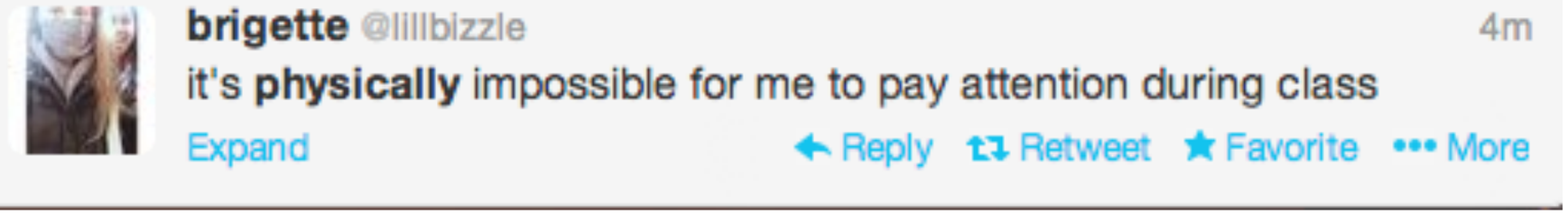
Not all languages distinguish two classes here.

When discussing “reality”, or attempting to be scientific, it is wise to remember that much of the language one uses is determined, not by facts, but by the culture around one.

If you think about it, are you clear what you mean by “mental” or “physical”?

When Doubting Thomas put his fingers in the wounds, what kind of proof was he looking for?

Many everyday uses of the term “physical” seem to mean something more like “experiential”



Discuss the many meanings of the word “physical” here.

British Empiricists

John Locke

Bishop Berkeley

David Hume

Contra Descartes, all knowledge is seen as grounded in the experience of the world mediated by the senses.

Beginning of *embodied* cognitive science?
The questions raised have a Heraclitian falvour.

Example: Molyneux's Question, posed to Locke:

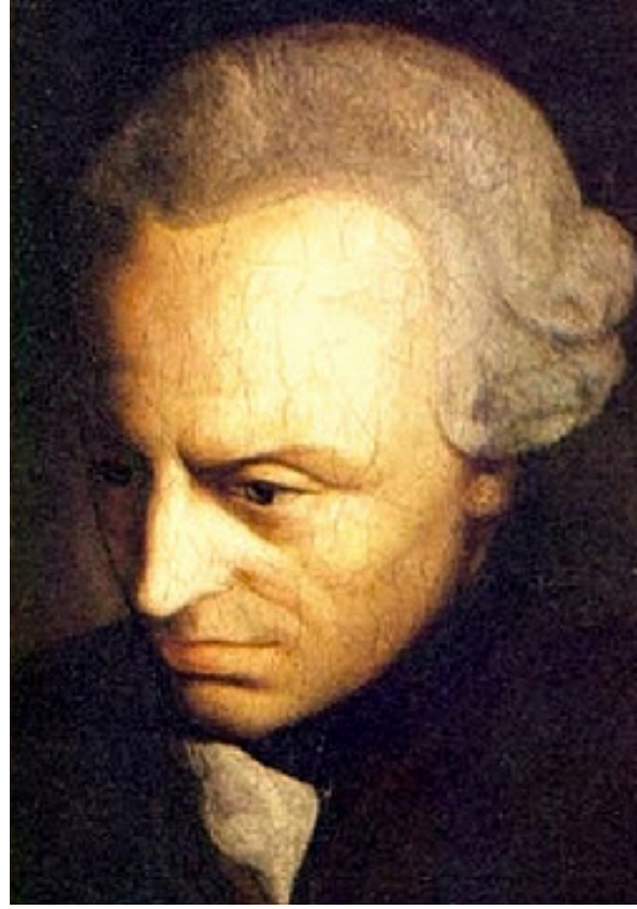
Suppose a Man born blind, and now adult, and taught by his touch to distinguish between a Cube, and a Sphere of the same metal, and nighly of the same bigness, so as to tell, when he felt one and t'other; which is the Cube, which the Sphere. Suppose then the Cube and Sphere placed on a Table, and the Blind Man to be made to see. Quaere, Whether by his sight, before he touch'd them, he could now distinguish, and tell, which is the Globe, which the Cube.

Amenable to empirical investigation. Rare example of a productive thought experiment.

Rationalism	**Empiricism**
Innate knowledge	Tabula rasa
Reason & Deduction	Inference & Induction
Certainty	Tentative knowledge
a priori	*a posteriori*

The debate is clouded by a persistent dichotomy between physical and mental, and the problematic nature of the *cogito*

Immanuel Kant



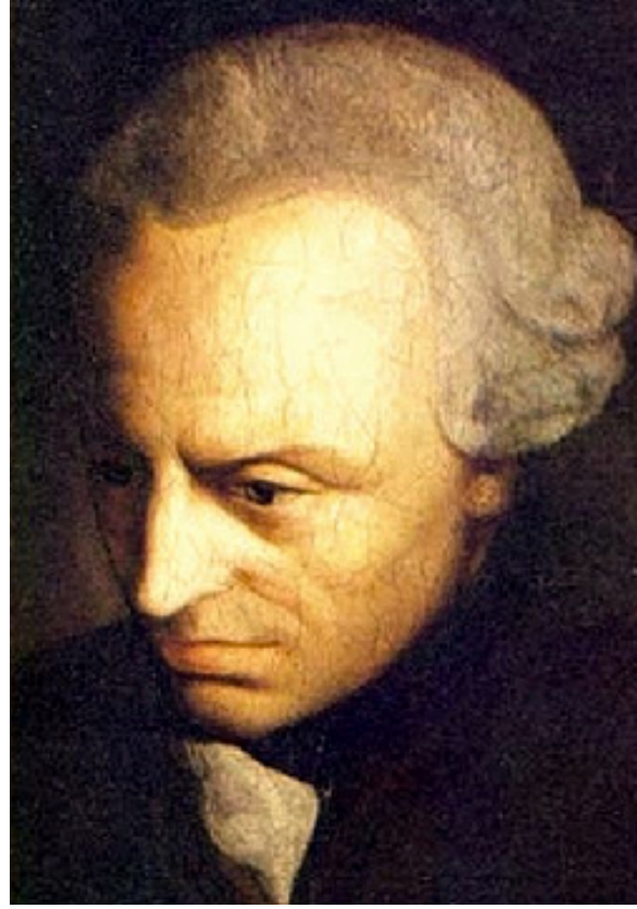
Attempted to synthesise the insights of the rationalist and empirical traditions

Regarded *space* and *time* as *a priori* of experience. LIkewise, *cause and effect* must be assumed to make sense before anything empirical is learned.

Had Newton's physics and concept of Natural Law to work with, but recognised that the apparent agency of the living would not admit of a mechanical description

Recognised that a finite being has finite epistemological limits, and that we meet the world on human terms

To Kant we owe the notion of the *transcendental subject.* Psychology, in particular, seems wedded to this notion, which is a little odd as Kant thought a science of psychology to be impossible.



Kant's legacy is complicated.

To some, he provided the framework for establishing a science of the mental

To others, he set up metaphysical confusion from which we are still liberating ourselves.

Kant's *transcendental subject* can be thought of as

1. Descartes' *cogito*, private and unobservable

wedded top

2. The empiricists' insistance that concepts and the patterns of thought are grounded in sensorimotor experience, here and now.

In this framing of things, the subject's relation to the world is necessarily mediated through representations

After Kant

Representational Approaches	Non-representational Approaches
Transcendental Subject in contact with a transcendental world through the medium of representations	Direct perception
	Phenomenological insights
A single fixed subject/object divide	Various approaches to subject/object relations

The birth of the science of Psychology

Towards the end of the 19th Century, the scientific method was being applied in very many domains, with enormous success in both understanding and in practical spin offs (technology).

Why not apply it to study of the human condition?

The ground in which psychology was born

17th - 18th C.

Mechanical Universe

Newton

Transcendental Subject

Kant

Cogito

Descartes

19th C.

- Kelvin
- Darwin
- Maxwell
- Mendeleev
- Boltzmann
- Planck

- James
- Wundt
- Fechner
- Dewey

Cummins

Dewey

Von Uexküll

Wundt

James

Locke

Kant

Spinoza

Hume

Wittgenstein

Descartes

Husserl

Bacon

Newton

Galileo

Einstein

Luther

Darwin

1500

1600

1700

1800

1900

2000

Q: What is Psychology a Science of?

Experience

Behaviour

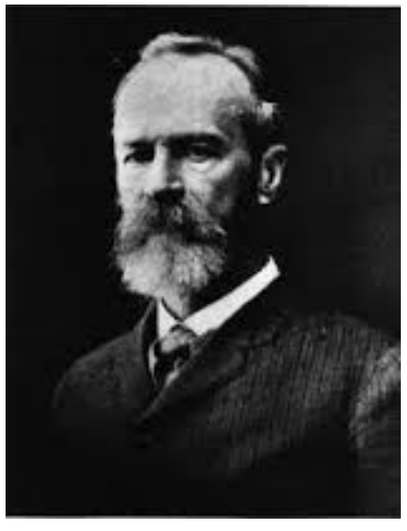
A few selected dates

1849: Hermann von Helmholz first measures the speed of neural signal transmission (ca 30 m/sec)

1860: Gustav Fechner publishes *Elemente der Psychophysik,* seeking to quantitatively relate measurable physical quantities to sensations

1879: Wilhelm Wundt establishes the first experimental psychology laboratory in Leipzig, Germany.

1890: William James publishes the Principles of Psychology

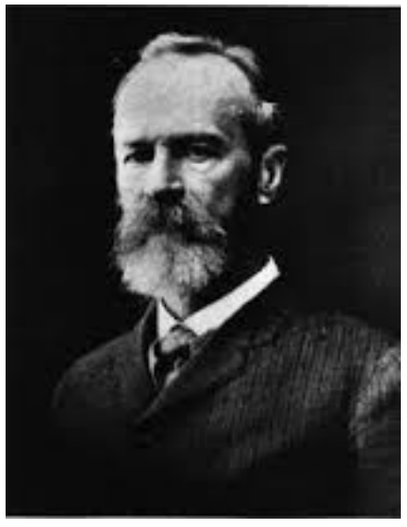


William James (USA, 1842 - 1910)

Brother of Henry James (novelist)

In a famous passage he says "Consciousness … does not appear to itself chopped up in bits. … it flows. A 'river' or a 'stream' are the metaphors by which it is most naturally described. In talking of it hereafter, let us call it the stream of thought, of consciousness, or of subjective life." (James, 1890, i, 239). He referred to the stream of consciousness as "... the ultimate fact for psychology." (James 1890, i, p 360).

The “stream of consciousness” idea has been more influential in literature (Joyce, Wolff, etc) than in science, though recent theories of consciousness may refer to it as a starting point.



William James (USA, 1842 - 1910)

Principles of Psychology
Varieties of Religious Experience

Strong interest in subjective experience
Influenced by Buddhist and Hindu philosophy as well as Western Science

Philosophically a *pragmatist*: rather than arguing for ever, let's see if a given idea or position can actually help us. (The start of the tradition of "self-help" in popular psychology)

Early Approaches

- Analysis (reason)
- **Psychophysics**
- Experiments (e.g. hypnosis)
- Introspection

A little illustration of psychophysics

200 Hz

300 Hz

400 Hz

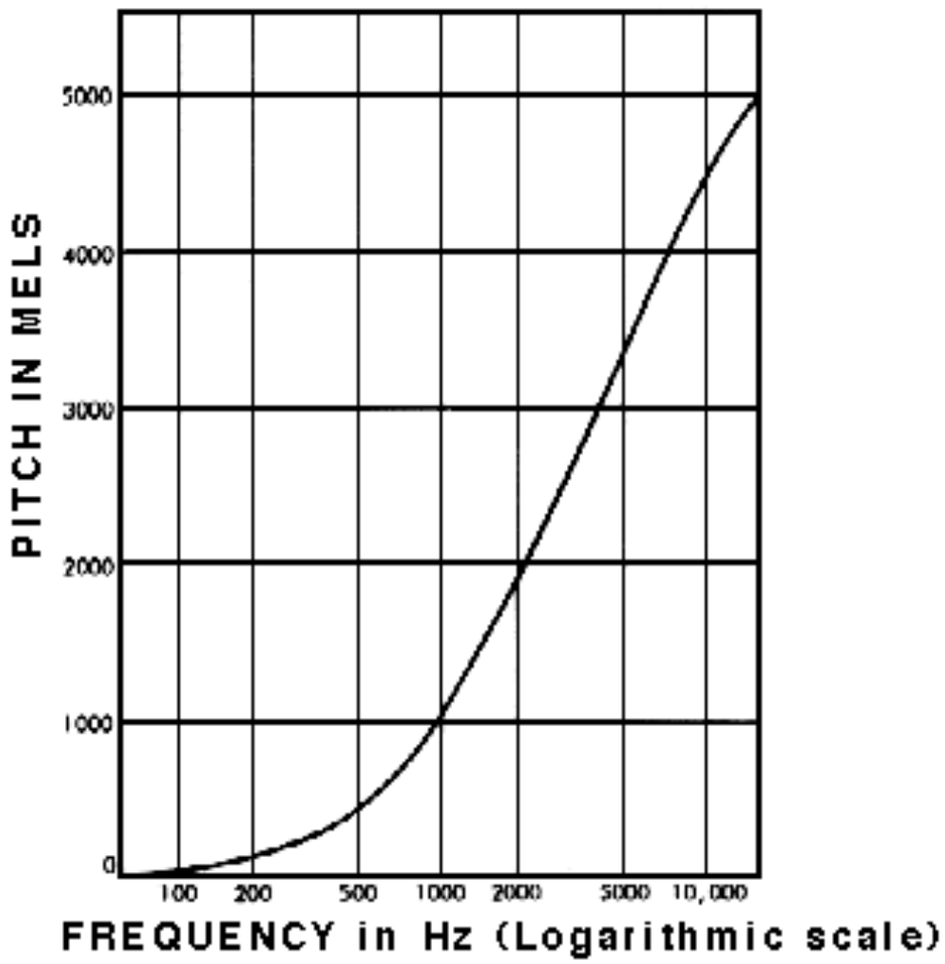
800 Hz

1600 Hz

We know how to measure the physical properties of things like sounds and light. But more work is required to understand how the physical properties relate to our perception. For example, we know that sounds of different frequencies are heard as different pitches, but we need to do experiments to find the relation between measured frequency and perceived pitch

We seek to establish the lawful relation between measurable properties such as frequency and perceived properties such as pitch.

How do you find out what someone perceives?



* ask them!
* judge if 2 stimuli are identical or not
* find just noticeable differences
* adjust two stimuli until they appear to be equal
* etc.

Measured Physical Property	Perceived Property
Frequency	Pitch
Amplitude	Loudness
Luminosity	Brightness
Chemical composition	Scent/Taste
Pressure	Perceived pressure
etc	

So psychophysics introduces us to many of the conundrums of cognitive science.

Are we establishing a mapping between two distinct domains?

What are the background assumptions about the nature of the *subject*?

Introspection

- One method among many
- Attempts to develop protocols that would allow for a degree of rigour
- Massively criticised later
- Still employed by almost everyone

A Fairy Story we tell Undergraduates

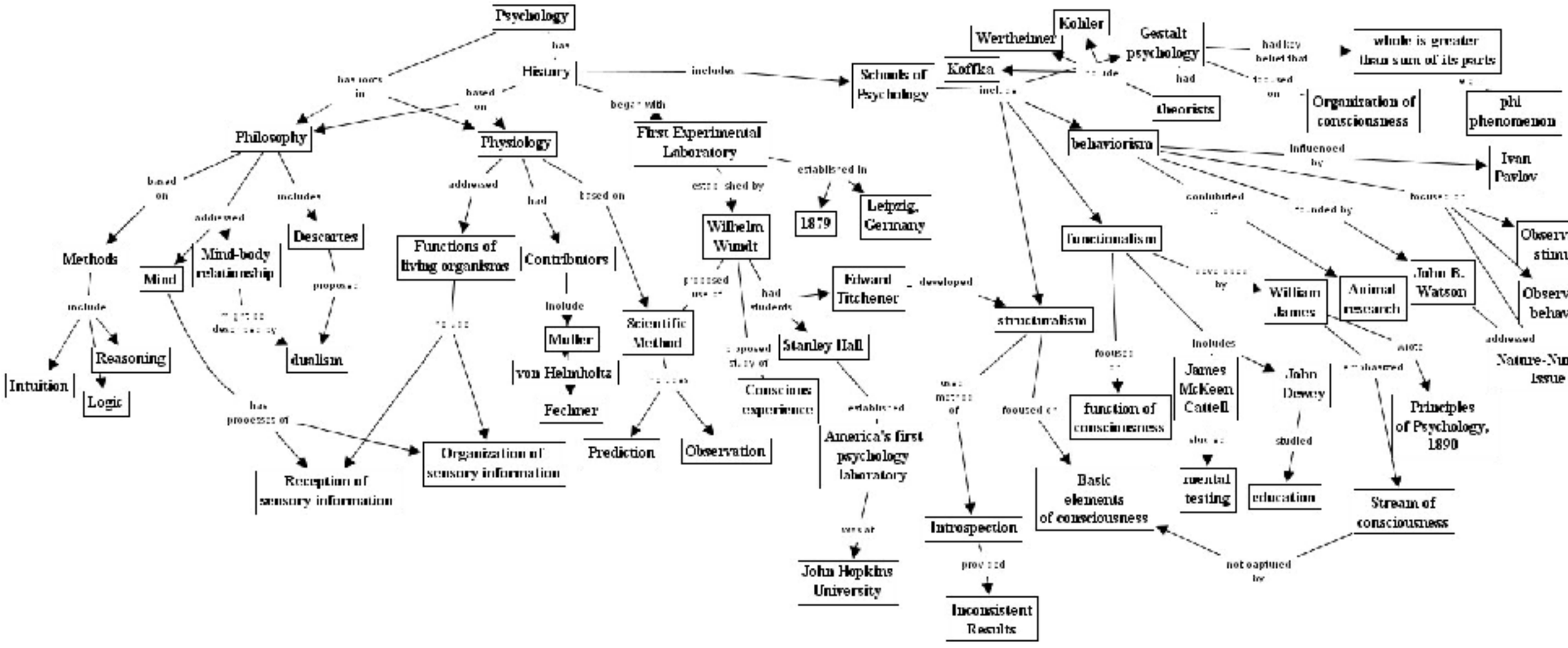
Methodological cornucopia including introspection

Behaviorism: no appeal to ghostly mental entities or processes

Cognitivism: mind as information processing

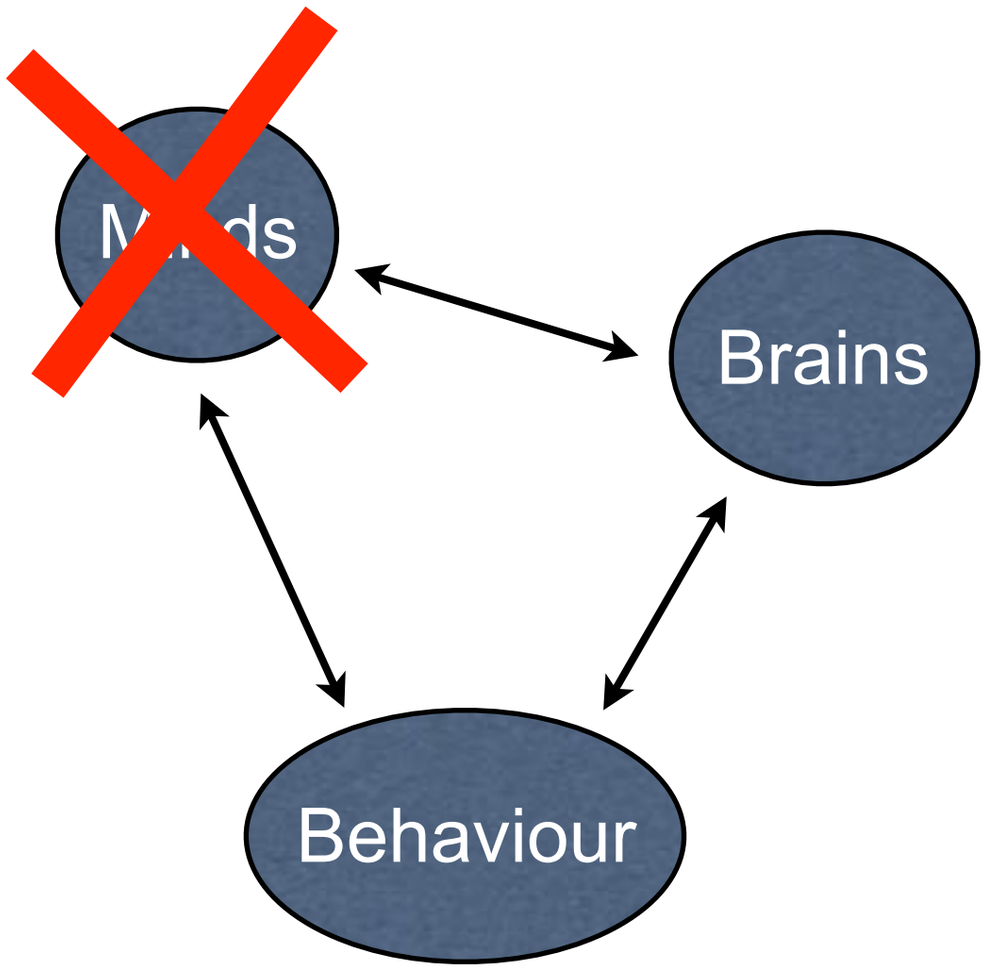
. . . Embodied approaches, etc

It’s a lot more complicated than that

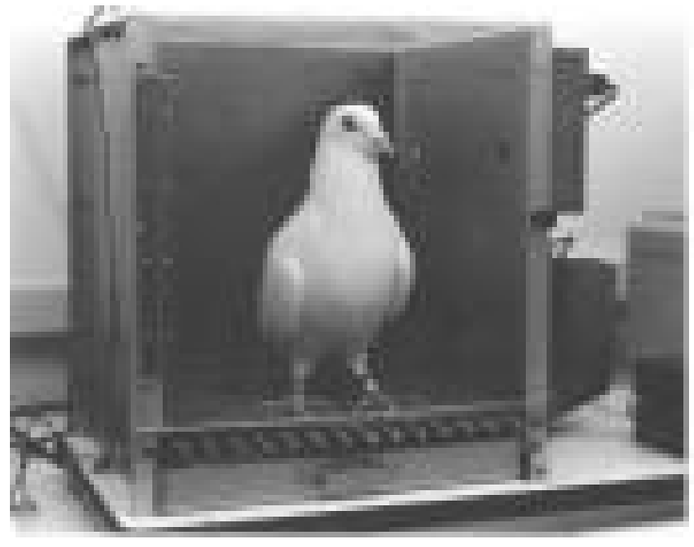


Behaviorism

- Outlawed appeal to unobservable mental states
- Attempted to be rigorous and scientific
- Comes in a variety of forms and extremes
- Most famous: B. F. Skinner


Minds
Brains
Behaviour

- Skinner introduced “Operant Conditioning”
- Behaviour is modified as a result of its consequences (reward/punishment)
- You burn yourself: you avoid fire
- Pigeons were kept at 2/3 of their normal weight -> starving
- By providing food at unpredictable times, pigeons preferentially reproduced the behaviour that ‘seemed’ to produce food.

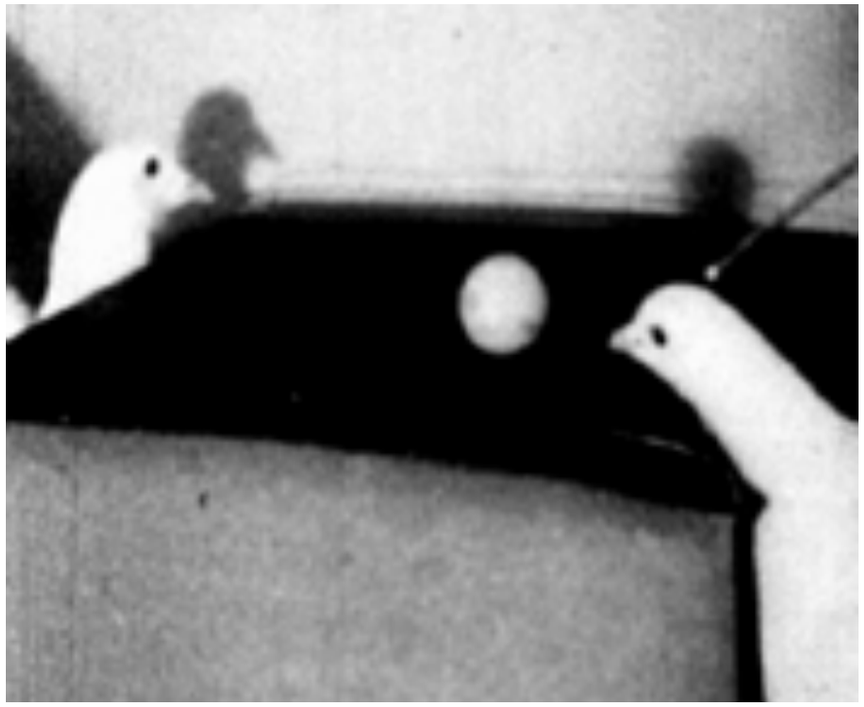


One bird was conditioned to turn counter-clockwise about the cage, making two or three turns between reinforcements. Another repeatedly thrust its head into one of the upper corners of the cage. A third developed a 'tossing' response, as if placing its head beneath an invisible bar and lifting it repeatedly. Two birds developed a pendulum motion of the head and body, in which the head was extended forward and swung from right to left with a sharp movement followed by a somewhat slower return. (see readings...)

Skinner's approach to understanding behaviour emphasized that any behaviour unfolds in a specific context.

This spreads the explanatory load over subject and world.

This insight is worth hanging onto.



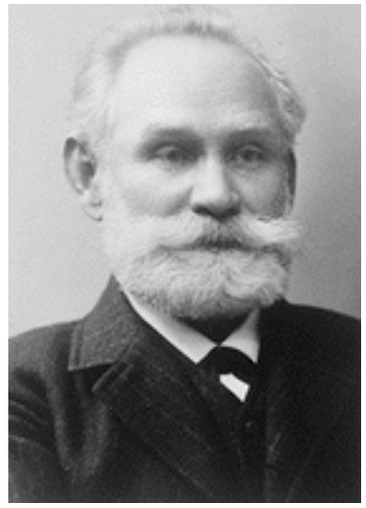
Behavioral shaping is effective in animal training

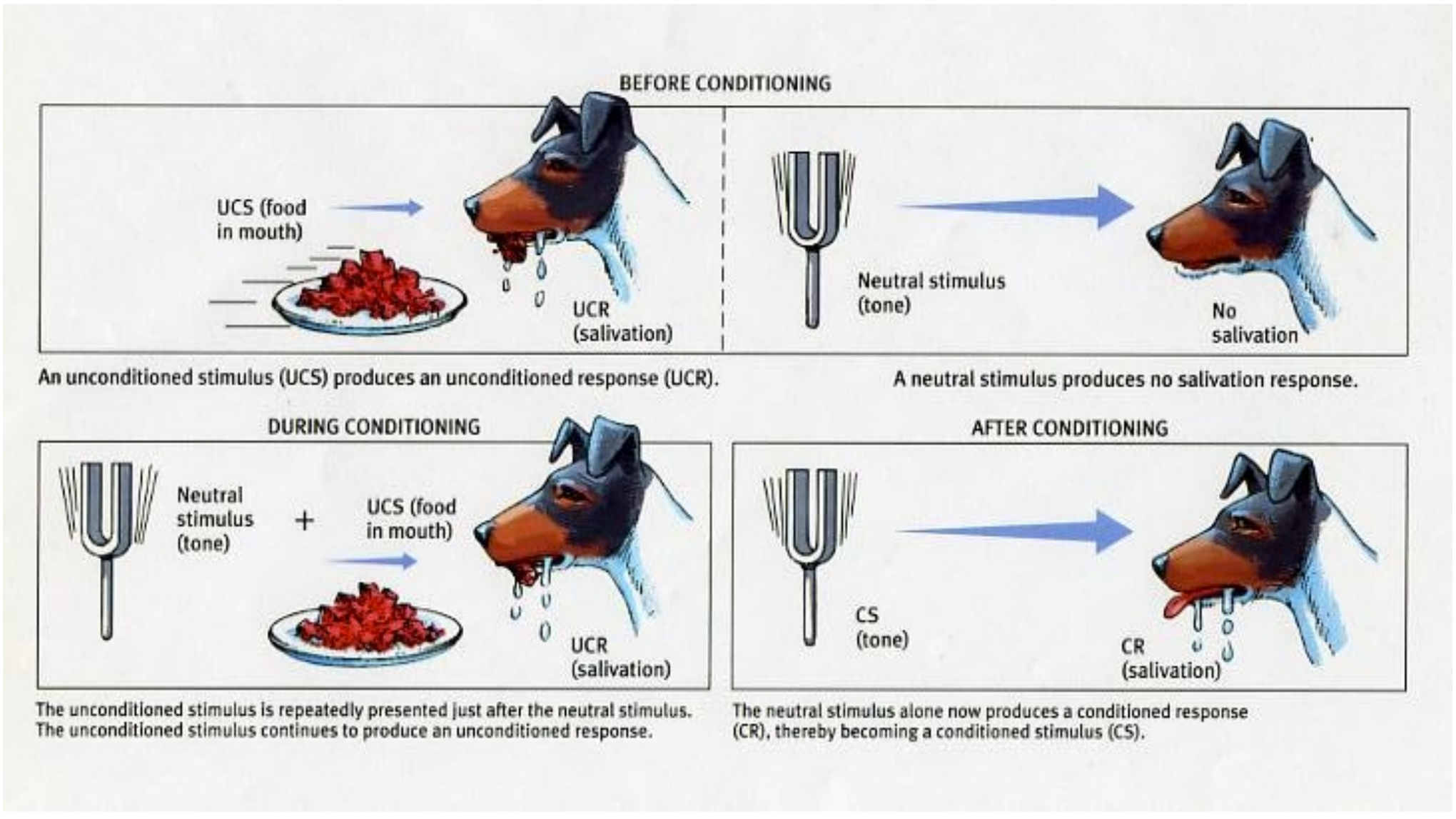
Classical Conditioning

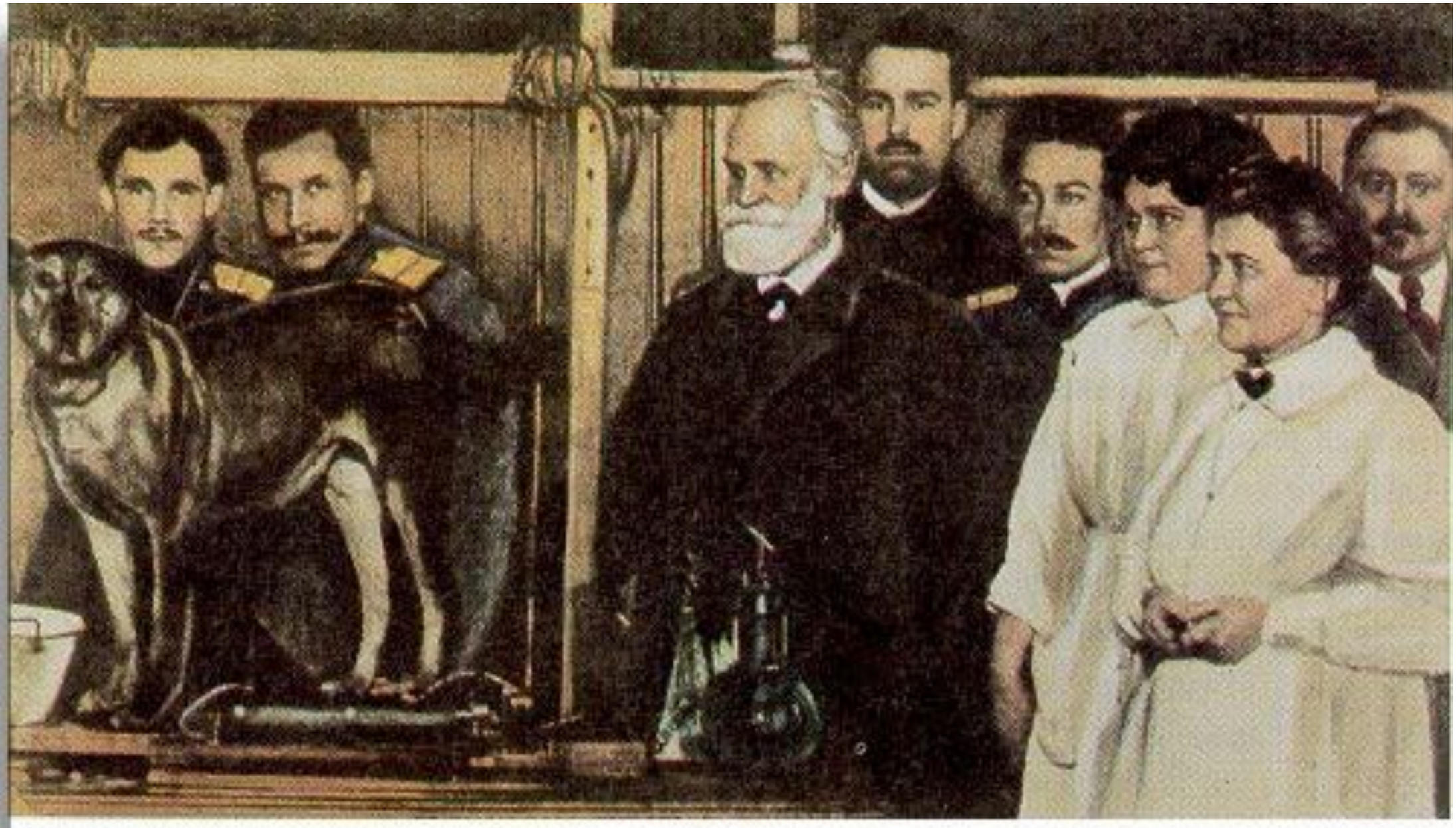
Stimulus.....Response

Involuntary learning

Ivan Pavlov







Pavlov(center) shown demonstrating classical conditioning to students at the Military Academy in Russia. © The Granger Collection

Umberto Maturana Heinz von Förster

https://www.youtube.com/watch?v=KM85u4AZpOU

Consider von Foerster's argument carefully.

How sure can you ever be that a "stimulus" plays the role you think it does?

What does the notion of stimulus & response assume about the endogenous activity of the nervous system?

An Ointment Full of Flies?

- Mechanistic view of the human spirit
- Denied much of the mental richness we all know
- Impoverished theory of learning
- Has nothing to say about *experience*

Not all behaviourists shared one world view.

Skinner was very aware of the importance of the context in which behaviour happened

Watson and Pavlov largely ignored context, hence stuffing responsibility into the head(?) of the subject

The Cognitive Turn

1943: McCulloch's *A logical calculus of the ideas immanent in nervous activity*

1945: Von Neumann architecture introduced

1946 - 1953: Macy Conferences to lay the foundations for a General Science of the Human Mind (Cybernetics)

1948: Claude Shannon "A mathematical theory of communication" Bell Labs

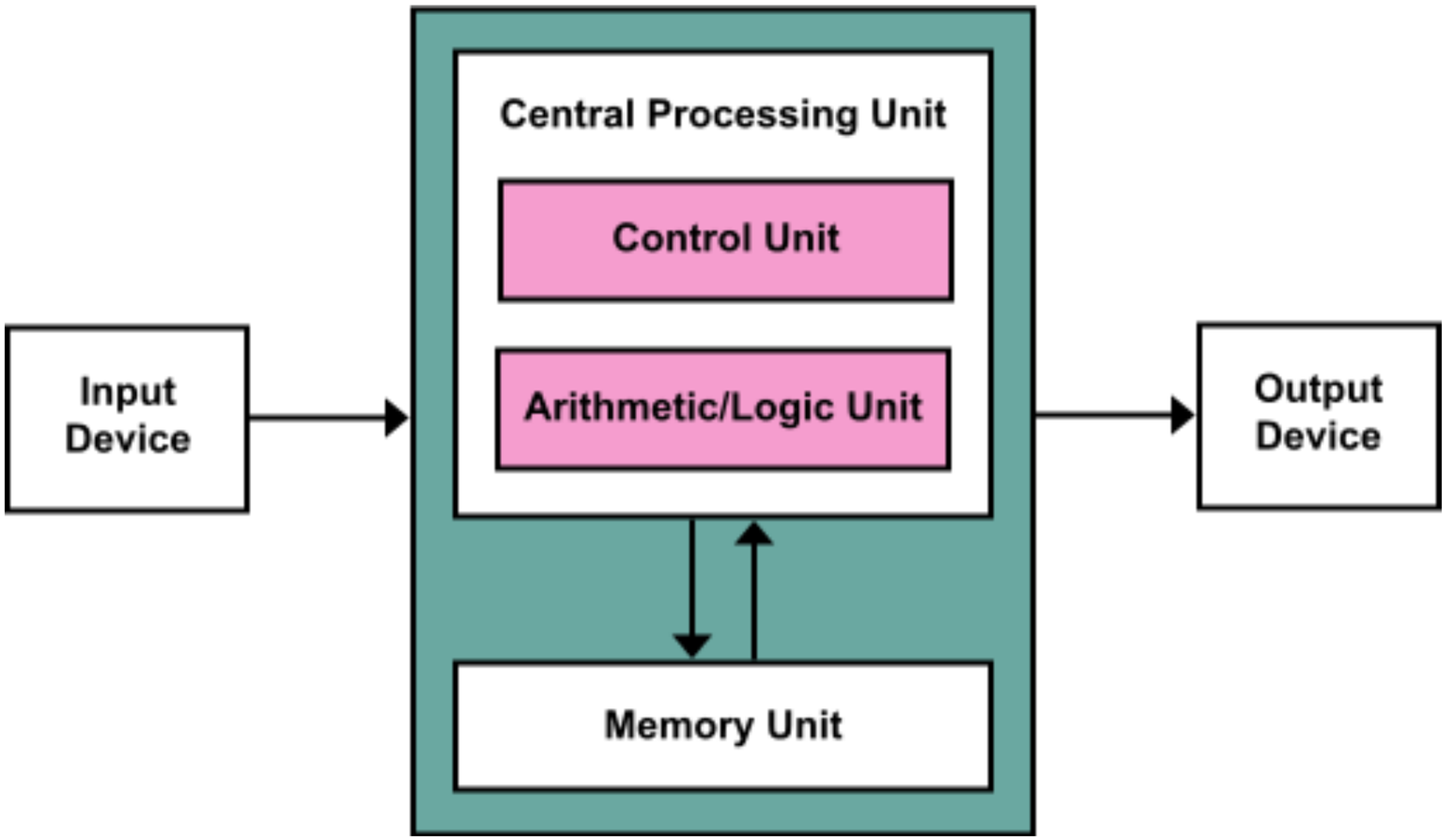
1950: Turing introduces the Turing Test

1959: Chomsky's review of Skinner's *Verbal Behavior. 1957: Syntactic Structures*

1967: Neisser's *Cognitive Psychology*

1973: Birth of the term *cognitive science* (Christopher Longuet-Higgins)

1945: Von Neumann architecture introduced



Basic architecture of the modern computer

1946 - 1953: Macy Conferences to lay the foundations for a General Science of the Human Mind (Cybernetics)

Norbert Wiener defined cybernetics in 1948 as "the scientific study of control and communication in the animal and the machine."

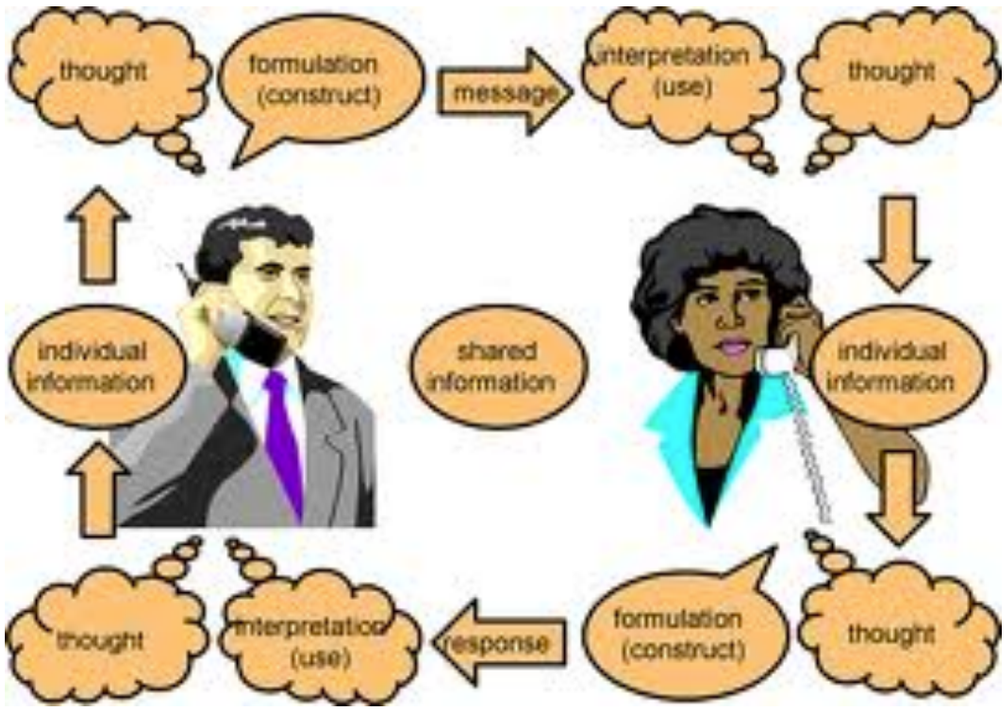
"A branch of mathematics dealing with problems of control, recursiveness, and information, focuses on forms and the patterns that connect."—Gregory Bateson

10th conf.

1953

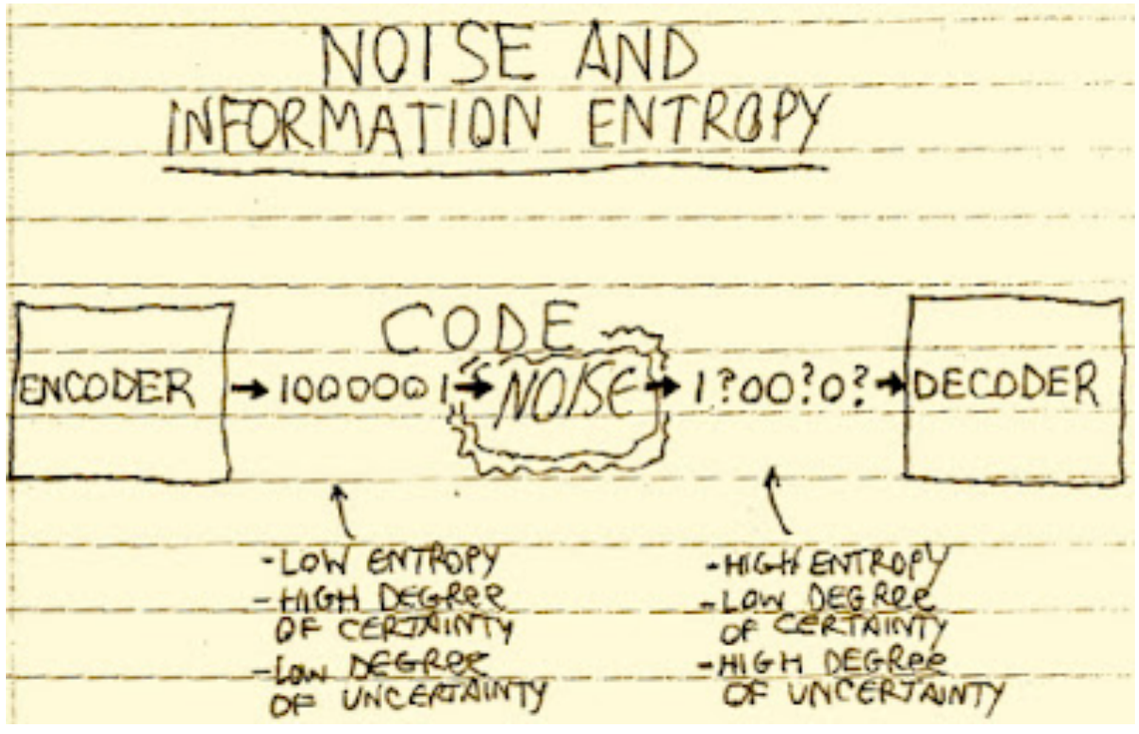
1st row (left to right)	T.C. Schneirla, Y. Bar-Hillel, Margaret Mead, Warren S. McCulloch, Jan Droogleever-Fortuyn, Yuen Ren Chao, W. Grey-Walter, Vahe E. Amassian.
2nd row (left to right)	Leonard J. Savage, Janet Freed Lynch, Gerhardt von Bonin, Lawrence S. Kubie, Lawrence K. Frank, Henry Quastler, Donald G. Marquis, Heinrich Kluver, F.S.C. Northrop.
3rd row (left to right):	Peggy Kubie, Henry Brosin, Gregory Bateson, Frank Fremont-Smith, John R. Bowman, G.E. Hutchinson, Hans Lukas Teuber, Julian H. Bigelow, Claude Shannon, Walter Pitts, Heinz von Foerster

1948: Claude Shannon “A mathematical theory of communication” Bell Labs

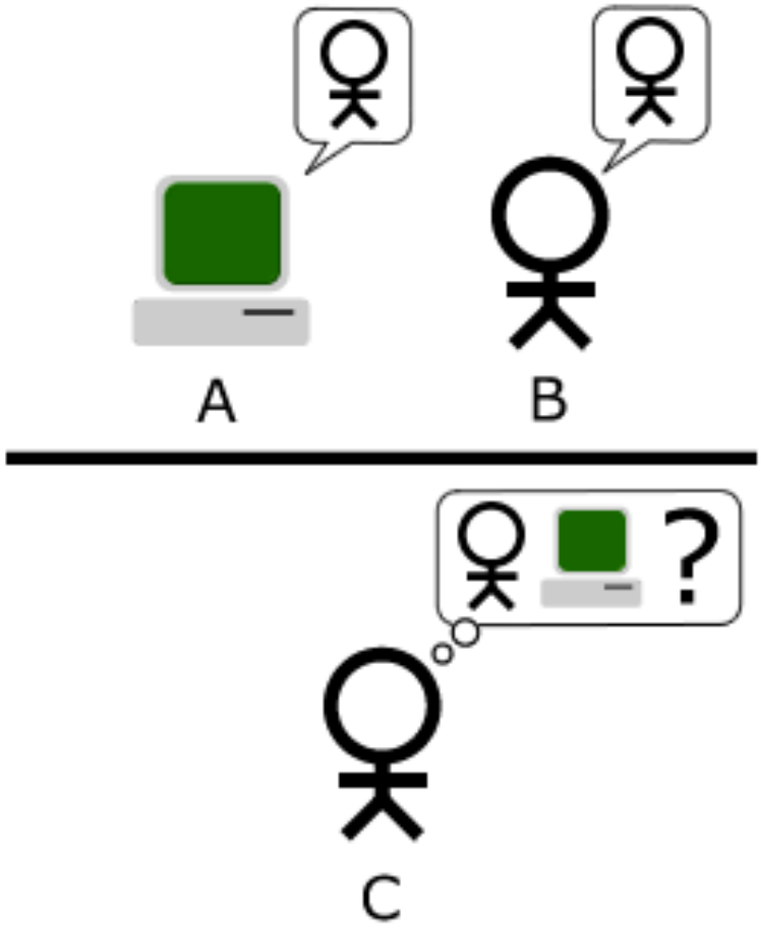


bits & bytes

entropy



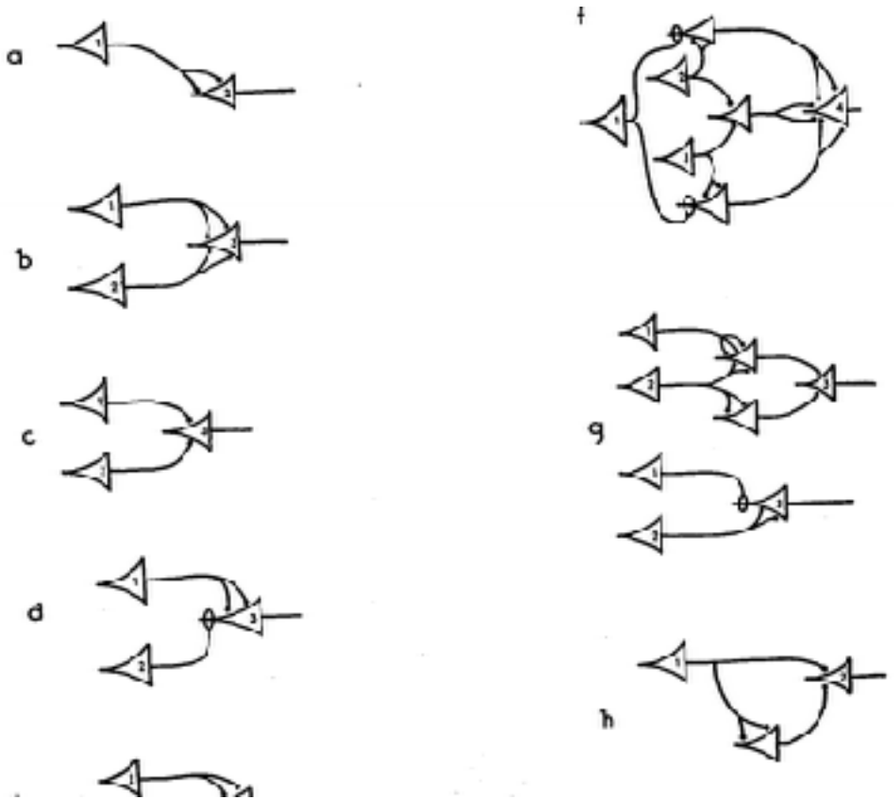
1950: Turing introduces the Turing Test



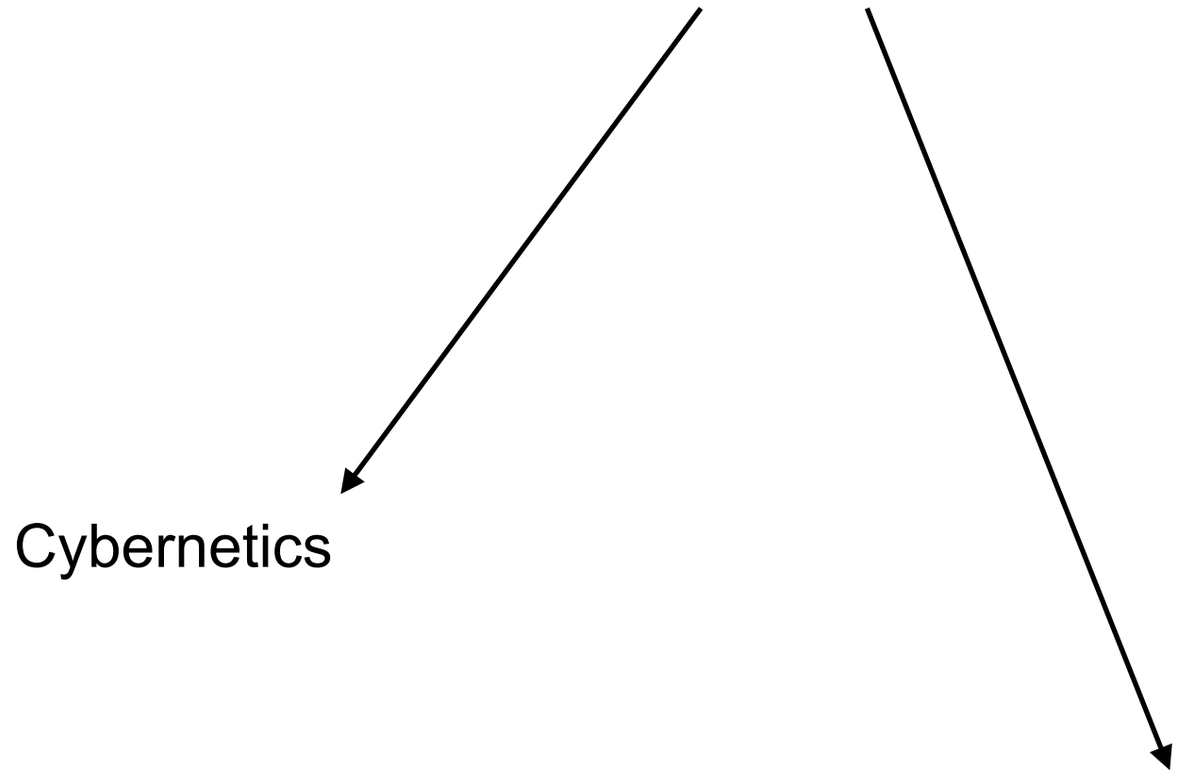
In 1980, this spawned the infamous Chinese Room argument by John Searle

1943: McCulloch's *A logical calculus of the ideas immanent in nervous activity*

Because of the "all-or-none" character of nervous activity, neural events and the relations among them can be treated by means of propositional logic. It is found that the behavior of every net can be described in these terms, with the addition of more complicated logical means for nets containing circles; and that for any logical expression satisfying certain conditions, one can find a net behaving in the fashion it describes. It is shown that many particular choices among possible neurophysiological assumptions are equivalent, in the sense that for every net behaving under one assumption, there exists another net which behaves under the other and gives the same results, although perhaps not in the same time. Various applications of the calculus are discussed.



Neurons as components in logical calculation

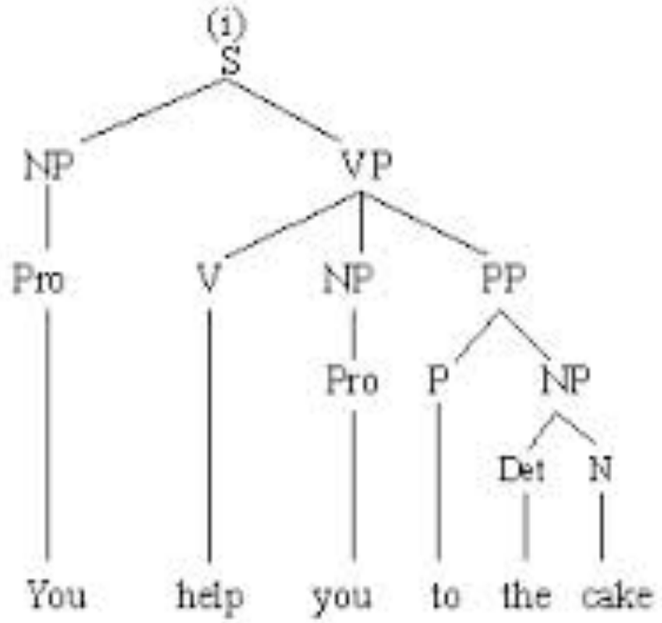


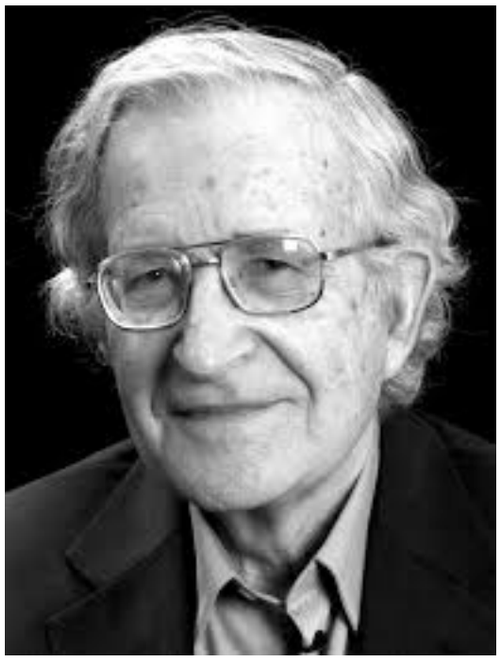
Artificial Intelligence

In the 1970s, funding favoured MIT, Marvin Minsky and AI.

1959: Chomsky's review of Skinner's *Verbal Behavior.* *1957: Syntactic Structures*

(1) S → NP + VP
(2) VP → Verb + NP
(3) NP → Det + N
(4) Verb → Aux + V
(5) Det → *the, a, . . .*
(6) N → *man, ball, . . .*
(7) Aux → *will, can, . . .*
(8) V → *hit, see, . . .*



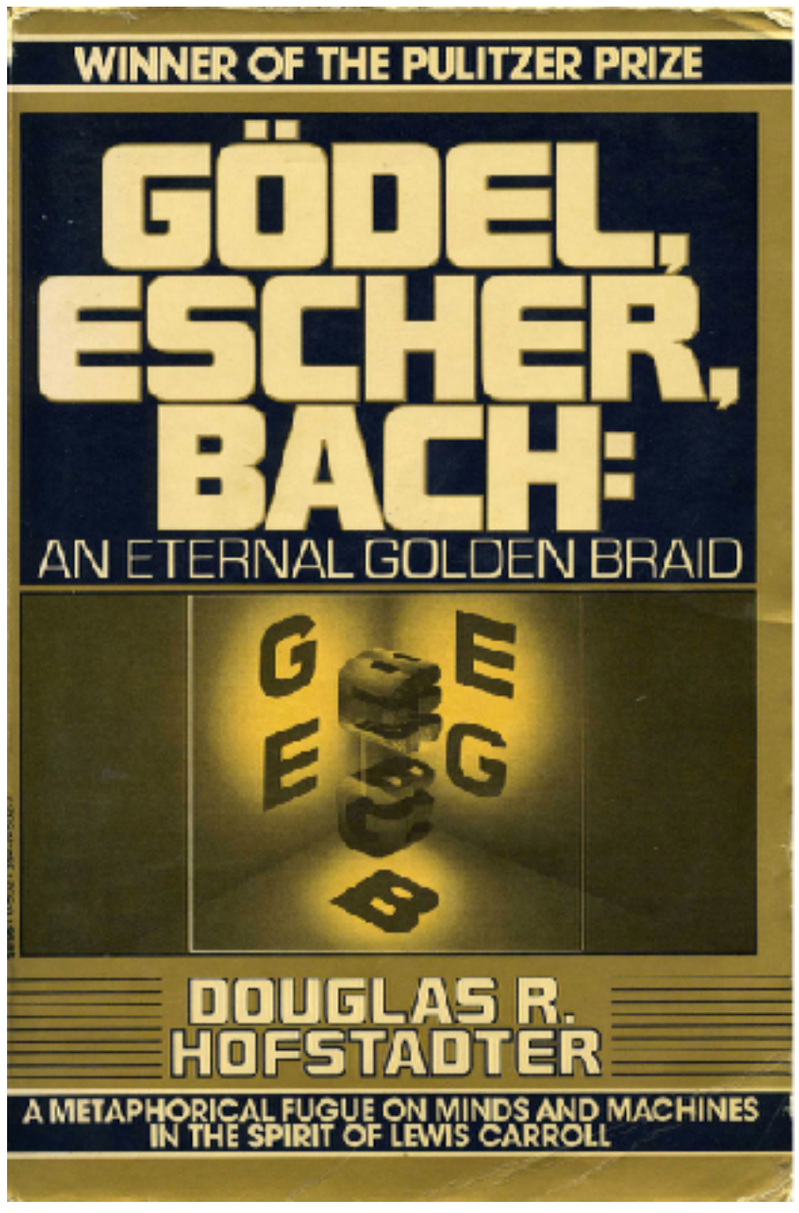


Innateness
Poverty of the stimulus
Creativity/Generativity

Symbols

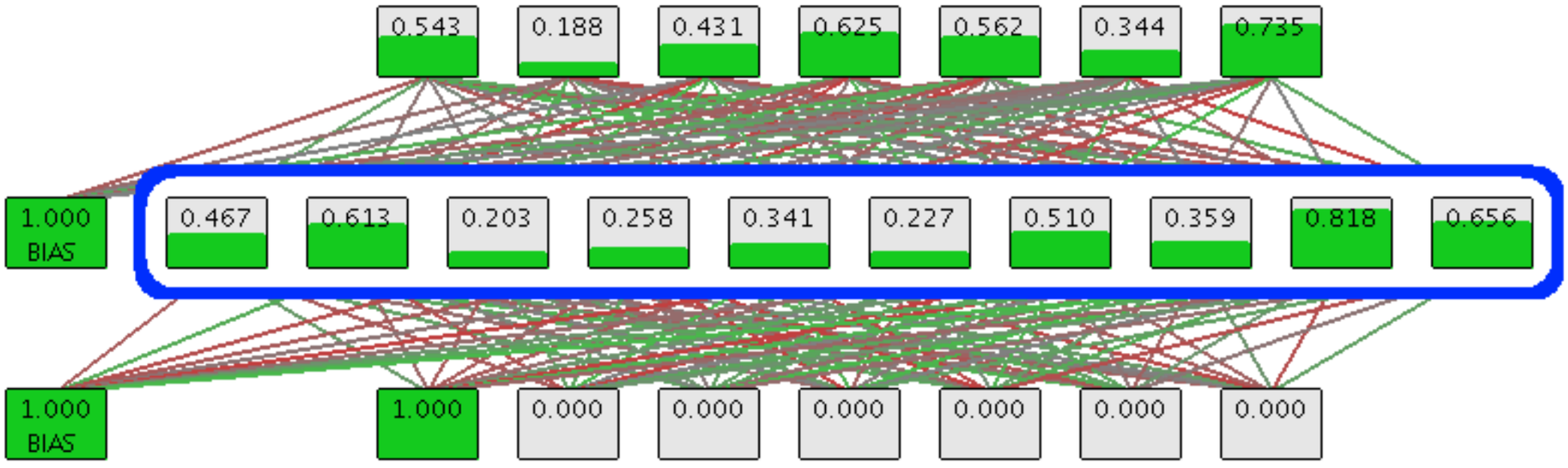
Sub-symbolic processing

Connectionism



Mid 1980's: Connectionism - Artificial Neural Networks

1986: Back Propagation algorithm
Allowed artificial neural networks to learn functions automatically from data.



Connectionism	Computationalism
Numerical processing	Word like symbols
Distributed representations	Syntactic processing
Associationism	Language of thought
Empirical push-back	Steeped in rationalist concerns
Generic learning mechanisms	Modular, domain-specific architecture
New kid on the block: Deep Learning	

The Embodied Turn

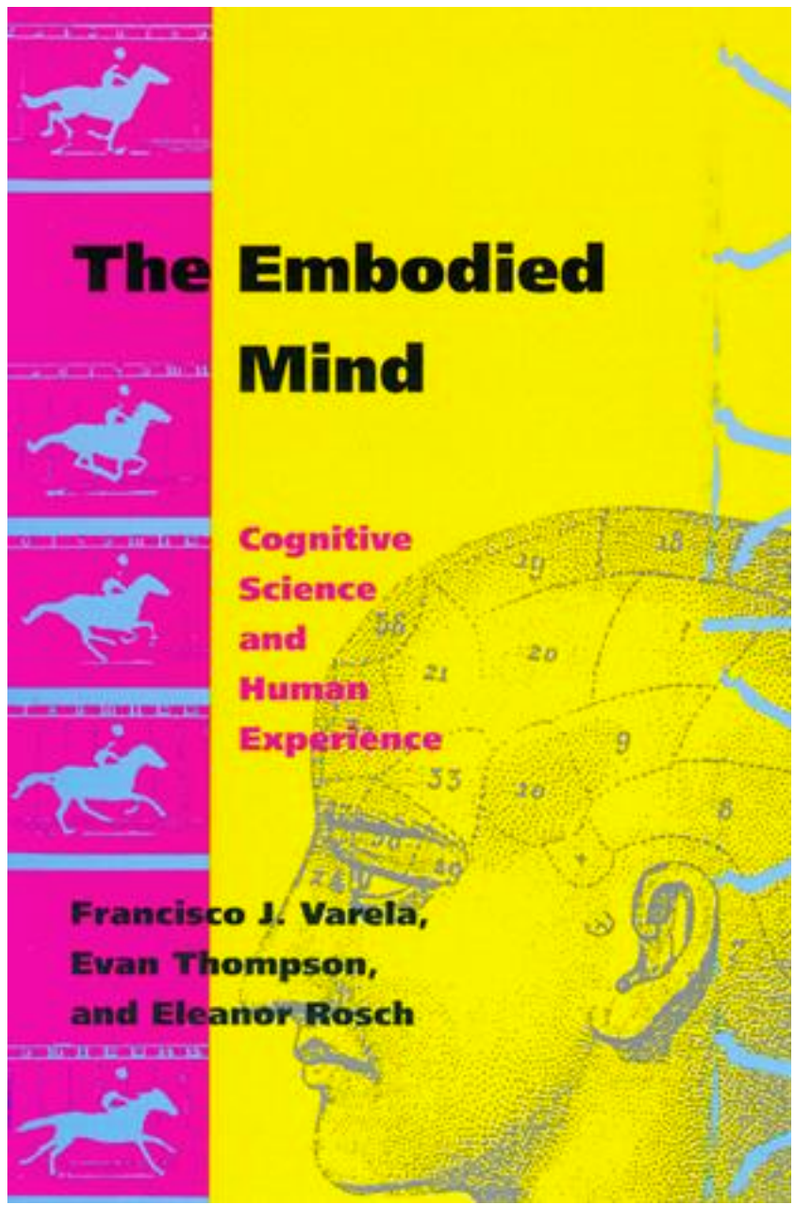
Convergence of many strands, some very old, some new

Rejection of mind/brain identity

Centrality of phenomenological concerns

Cognition as a form of activity

Strong *biological* basis



1991

4E as a cover term:

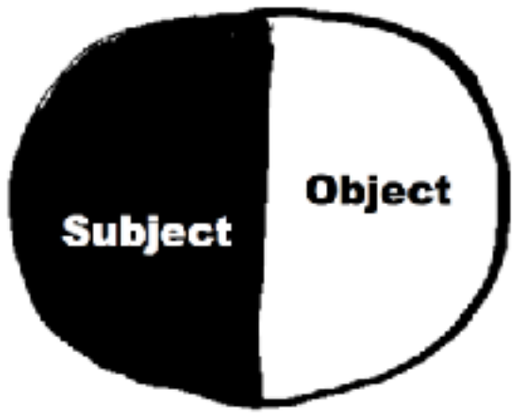
Embodied

Extended

Embedded

Enactive

Computational approaches



4-E approaches

Persistent Oppositions

Presentism	Eternalism
Presence	Representation
Becoming	Being
Senses & Experience	Reason & logic
Mind/Body/World	Mind vs World